PROJECT COMPLETION REPORT

OWRR PROJECT No. A-034-ARIZ

Use of Amendments to Reduce Water Requirements for Stand Establishment of Small-Seeded Crops

Agreement No. 14-31-0001-5003

Project Dates: July 1, 1972-June 30, 1975

Principal Investigators

R. E. Dennis
C. W. Edmond
C. W. Robbins

The University of Arizona
Tucson, Arizona

August, 1975

Acknowledgement - The work upon which this project is based was supported by funds provided by the United States Department of Interior, Office of Water Research and Technology, as authorized under the Water Resources Research Act of 1964.

ABSTRACT

Soil crusting after planting is a serious problem in stand establishment of small-seeded crops in the Southwest. When crusting occurs in a saline, warm soil, stand establishment problems are especially severe. It is customary to use costly irrigation water to keep seedbed surfaces moist after planting to reduce soil crusting and to lower soil temperatures.

Phosphoric acid (24% and 12%) and sulfuric acid (95%) were evaluated to determine their effectiveness in reducing soil crusting and reducing the amount of water required to obtain stands of sugarbeets, alfalfa, wheat and barley.

Phosphoric acid, applied in 4-6 cm bands over the seed row at planting and before irrigation, reduced crusting and increased sugarbeet and alfalfa seedling emergence. Emerged seedlings from phosphoric acid treated plots were larger and one irrigation (10-15 ha cm/ha) was saved in stand establishment. Sulfuric acid applied in bands reduced soil crusting. Soluble salts in the seed zone resulting from band application of sulfuric acid killed or damaged seedlings. Sulfuric acid, when applied in irrigation water to saline-sodic soils, improved plant growth and water use efficiency.

Key Words: Soil crusting, seedling emergence, water saving, water use efficiency, sugarbeets, alfalfa, sulfuric acid, phosphoric acid, soil amendments.

INTRODUCTION

The establishment of small-seeded crops in irrigated desert environments, is seriously affected by soil crusting, high soil temperatures and soil salinity. Saline soils, especially those with fine texture, disperse and form crusts when the surface has been wetted and then allowed to dry.

Soil crusting follows the mechanical destruction of aggregates, washing of fine particles into inter-aggregate spaces, and the rupture of soil aggregates by trapped air. Soil crusts are effective barriers to seedling emergence.

Problems of soil crusting are compounded when small-seeded crops are planted in warm, saline soil, a practice often required in irrigated deserts. Germination percentage and vigor decrease dramatically with increasing temperature and salinity. When soil crusting occurs additionally, stand establishment failures are common.

Farmers keep the surface soil moist after planting crops such as sugarbeets and alfalfa, to reduce the energy required for seedling emergence. The application of frequent, light irrigations is effective in reducing soil crusting but it wastes water and is costly.

This research evaluated phosphoric and sulfuric acids and several other soil amendments to determine their effectiveness in reducing soil crusting, thereby permitting a saving of irrigation water during stand establishment. Other potential uses of sulfuric acid and related cultural practices were also investigated.

OBJECTIVES

The objectives of this project were:

1. To evaluate phosphoric and sulfuric acids and other amendments as anti-soil crustants and to determine their effect on seedling emergence and the water requirement for stand establishment.
2. To investigate the use of sulfuric acid as a soil amendment for reducing salinity in saline-alkali soils, thereby improving water use efficiency.
3. To develop appropriate methods of applying soil crust inhibiting amendments under laboratory and field conditions.

DESCRIPTIVE REPORT OF RESEARCH PROCEDURES

Chemicals containing sulfur have been used for years in the reclamation of saline-sodic soils. After application of sulfur containing chemicals, soluble calcium is released forming gypsum. Gypsum acts to replace adsorbed sodium and this reaction yields sodium sulfate. Other sulfates are also produced. Since sulfates are soluble they may be leached to lower soil depths where they are out of the reach of roots. Sulfuric acid, as produced in air pollution reducing procedures now used in copper and other mines, is an excellent soil amendment for saline-sodic soils.

Johnson and Law (1966) applied concentrated sulfuric acid to the soil surface in bands above the seed-row, after planting sugarbeets in Utah. In their research this practice reduced soil crusting and increased seedling emergence 42 to 50%. Robbins, Carter and Leggett (1972) applied

657 l/ha of phosphoric acid (24%) in 6 cm bands on the soil surface over sugarbeet rows, simultaneous with planting, in Idaho and obtained increases of seedling emergence up to 80%. These and related encouraging results formed the basis for this research project.

Other soil amendments used in this research were ferric and ferrous sulfate, a commercial latex formulation and sawdust. These materials were selected because of their ease of handling and availability.

Plan Followed for Conduct of Research

First Year Experiments (1972-1973)

Two laboratory and six field experiments were conducted to identify amendments with the greatest promise of fulfilling project objectives and to lay the foundation for future studies. Laboratory experiments were conducted in an open-air enclosure at the University of Arizona Campbell Avenue Branch Experimental Farm and field research was located on six central Arizona farms.

Soil from the Wade farm (pH 8.0 and $EC_e \times 10^3 = 6.4$) near Buckeye, Arizona was used for the first year laboratory studies. This silty-clay loam contained 59.8, 21.8 and 18.4% silt, clay and sand respectively. During the first year all research was with sugarbeets, *Beta vulgaris* L., cultivar US-H9B.

Simulated beds were established in 191, plastic lined, metal containers for the laboratory experiments. Three rates of phosphoric and of sulfuric acid were applied to the soil surface in 7.5 cm bands immediately after planting and before application of the germination irrigation.

Three levels of irrigation were used in each laboratory experiment. In the first laboratory experiment equal amounts of water were applied to each side of the seed row. All irrigation water was applied to one side of the seed row in the second laboratory experiment. Temperature and humidity in the soil at seed depth and above the soil, were carefully monitored during laboratory and field experiments.

The field experiments during the first year were placed on six farms located in central Arizona. At each location one group of plots was established using six different materials with anti-crustant potential. A second series of plots was established, with power equipment designed and constructed for this purpose, at each location with three rates of phosphoric acid only. All treatments in each group of plots were replicated four times.

Appropriate seedling counts and harvests were made and beet roots were harvested at each on-farm location in June 1973 to determine sugar yield.

Second Year Experiments (1973-1974)

During first year experiments phosphoric acid was found superior to other materials used to achieve anti-crustant objectives. Research concerning the reduction of crusting and resultant saving of water was conducted using phosphoric acid only during the second year. Principal effort in this regard was at the University of Arizona Mesa Branch Experimental Farm and on two farms in central Arizona.

Irrigation level was a variable for the Branch Station and on-farm tests during the second year. Phosphoric acid was applied mechanically using methods developed during the first year. Seedling count and weight data were obtained at the Mesa Branch Experimental Farm and at each of the on-farm test locations. Additonally beet yield data were obtained for the on-farm plots.

Sulfuric acid was used in two types of experiments during the second year. It was reasoned that soluble salts produced by application of sulfuric acid would slow plant growth and that this might increase sugar storage by sugarbeets during the period immediately preceding harvest. Sulfuric acid and several growth regulators were used in such experiments at two locations in central Arizona. Sulfuric acid was also used at three rates and with three leaching regimes to determine its effectiveness in reducing salinity of a saline-sodic soil. This experiment also included an evaluation of the relative salt tolerance of several spring wheat cultivars.

Third Year (1974-1975)

Experimentation during the third year was principally limited to exploiting first and second year findings. Phosphoric acid was applied to the soil surface over alfalfa seedings in laboratory tests and at the University of Arizona Mesa Branch Experimental Farm. Soil for the laboratory experiment was from plots later used for field research. This research included an irrigation variable. Additionally, field research during the third year of this project evaluated the interaction of acid treatment with alfalfa seeding method and seeding rate.

FINDINGS AND CONCLUSIONS

The findings and conclusions for each of the three year segments of this project are presented in this section.

First Year (1972-1973)

Sugarbeet seedling emergence, seedling weight and efficiency of water use were greatest for plants in plots that received surface applied phosphoric acid. Increases in these parameters were significant when 657 and 1340 l/ha of 24% phosphoric acid were applied in a 7.5 cm band above the seed row. Surface applied sulfuric acid reduced seedling emergence and especially seedling survival. Sulfuric acid applications increased the amount of soluble salt in the seed zone and this salt damaged and in many instances killed sugarbeet seedlings. Application of phosphoric acid resulted in increased seedling emergence and weight while sulfuric acid applications significantly reduced sugarbeet seedling number and weight. Application of irrigation water to both sides of the simulated bed increased soluble salts in the seed zone.

In the second laboratory experiment, phosphoric acid was applied at the rate of 657 and sulfuric acid 375 l/ha. Irrigation in the second laboratory experiment was on one side only of each of the simulated beds. The second experiment duplicated and confirmed results obtained in the first experiment. Phosphoric acid significantly increased seedling emergence and seedling size, and saved water in stand establishment. Sulfuric acid had a negative effect on each of these parameters.

Field plot research during the first year confirmed beneficial effects on surface applied phosphoric acid of sugarbeet seedling emergence and improve sugarbeet seedling emergence. Sulfuric acid reduced seedling emergence and the size and number of emerged seedlings. Beneficial effects of phosphoric acid on seedling emergence did not carry through to harvest in terms of sugar yield in field tests. A successful power sprayer was developed and used in field tests during the first year. Sulfuric acid was difficult to use, because of its caustic effects, except under the most carefully controlled conditions.

Second Year (1973-1974)

Sulfuric acid was demonstrated to be an excellent amendment for reducing the amount of sodium in a saline-sodic soil in second year tests. The soil for this laboratory experiment was very high in salt with an EC_e 10^3 of 20.2 mmhos. Application of 18,900 l/ha of sulfuric acid (95%) with 30 cm of applied water for leaching altered the makeup of the soil used so that wheat and barley seedling emergence and early growth were satisfactory. This experiment also provided an opportunity to evaluate the relative salt tolerances of several spring wheats. The cultivar Cajeme 71 was found to have salt tolerance comparable to that of Arivat barley. Demonstration of the high salt tolerance of this wheat opens several thousand acres of saline soil of the irrigated deserts to the production of this important crop.

During the second year field plots were established in central Arizona to study further the water saving value of surface applied phosphoric acid. Results obtained in these tests again indicated that one irrigation could be saved in sugarbeet stand establishment by the application of phosphoric acid. Sugarbeet seedling emergence with one irrigation was significantly greater than with two irrigations. The yield of sugar was not significantly different from plants in plots that received two as compared to those receiving only one germination irrigation.

Third Year (1974-1975)

During the third year of this study an effort was made to carry the successful results with sugarbeets to alfalfa. Alfalfa seeds planted at 0.7 cm depth produced 44% more seedlings than when planted at a depth of 1.4 cm. The number of emerged seedlings and the weight of seedlings from plots treated with surface applied phosphoric acid were significantly greater than from the untreated check. Alfalfa seedlings used phosphorus from the phosphoric acid. This use of phosphorus played a role in increased seedling vigor and weight of sugarbeet seedlings. It is now desirable to develop precision equipment for the application of narrow bands of phosphoric acid over the rows when small-seeded plants are seeded.

OVERALL SUMMARY AND CONCLUSIONS

This study was prompted by problems concerned with the establishment of stands of crops having small seed and especially with the amount of water required to achieve stand establishment. The principal objective was to identify methods of using soil amendments so that water could be saved in stand establishment.

In the first year of this research several soil amendment materials, especially sulfuric acid and phosphoric acid, were evaluated. Emphasis during this period was on determination of the amendments' effect upon soil crusting, increasing seedling emergence and most important, water savings.

Laboratory and field experiments revealed the superiority of phosphoric acid in achieving project objectives. Phosphoric acid, while caustic, was handled with relative safety. Phosphoric acid helped to prevent the formation of surface crusts and improved the emergence of sugarbeet and alfalfa seedlings an average of more than 20%. Phosphoric acid also provided fertilizer phosphorus and this enhanced seedling weight and vigor. This research indicates that routine band application of phosphoric acid for sugarbeet and alfalfa plantings made in fine-textured soils would be an economic practice and that it would result in saving irrigation water.

Sulfuric acid, while excellent as a soil amendment for reducing salinity, produced negative effects when applied on the surface of the soil over planted seed. The acid was dangerous to work with and application of the acid increased the amount of soluble salt in the seed zone. The high content of soluble salts injured and often killed sugarbeet seedlings.

In the next phase of this research there is a need to develop commercial models of precision equipment for the application of phosphoric acid. These machines should be designed so as to make an application only one to two cm wide above the seed row. A narrow band of precision applied phosphoric acid would increase the number, size, and vigor of emerged seedlings for crops like sugarbeets and alfalfa.

Increased number and vigor of seedlings would be one important contribution. Probably more important would be the saving of at least one irrigation by such application.

REFERENCES CITED

1. Adamson, R. M., and E. F. Maas. 1971. Sawdust and other soil substitutes and amendments in greenhouse tomato production. Hort. Sci. 6:397-399.

2. Arndt, W. 1965. The impedance of soil seals and the forces of emerging seedlings. Aust. J. Soil Res. 3:55-67.

3. Dennis, R. E., K. C. Hamilton, M. A. Massengale, and M. H. Schonhorst. 1965. Alfalfa for forage production in Arizona. The University of Arizona, Bull. A-16 p. 10-16.

4. Dennis, R. E., and J. M. Nelson. 1971. Sugarbeets in Arizona. Univ. of Arizona Bull. A-71. 6 p.

5. Eavis, B. W. 1972. Soil physical condition affecting seedling root growth. Plant and Soil 37:151-158.

6. Francois, L. E., and J. R. Goodin. 1972. Interaction of temperature and salinity on sugarbeet germination. Agron. J. 64:272-273.

7. Frelich, James R., E. H. Jensen, and R. O. Gifford. 1973. Effect of crust rigidity and osmotic potential on emergence of six grass species. Agron. J. 65:26-30.

8. Hanks, R. G., and F. C. Thorp. 1957. Seedling emergence of wheat, grain sorghum and soybeans as influenced by soil crust strength and moisture content. Soil Sci. Soc. Amer. Proc. 21:357-359.

9. Hunter, J. R. 1951. Some factors affecting germination in sugarbeet seed (<u>Beta vulgaris</u> L.). Ph.D. thesis, Michigan State Univ. 95 p.

10. Johnson, R. C., and G. E. Law. 1967. Controlling soil crusting in sugarbeet fields by applying sulfuric acid. J. Amer. Soc. Sugar Beet Technol. 14:615-618.

11. Kathib, I. H., and M. A. Massengale. 1966. Effect of certain salts on germination of alfalfa and berseem clover. Progress. Agr. in Arizona 18:21-23.

12. Overstreet, R. J., J. C. Martin, and H. M. King. 1951. Gypsum, sulphur, sulphuric acid for reclaiming an alkali soil of the Fresno series. Hilgardia 21:113-127.

13. Richards, L. A., ed. 1954. Diagnosis and improvement of saline and alkali soils. USDA Agricultural Handbook 60. U. S. Government Printing Office, Washington, D. C.

14. Robbins, C. W., D. L. Carter, and G. E. Leggett. 1972. Controlling soil crusting with phosphoric acid to enhance seedling emergence. Agron. J. 64:180-183.

15. Taylor, H. M. 1962. Seedling emergence of wheat, grain sorghum and guar as affected by rigidity and thickness of surface crust. Soil Sci. Proc. 26:431-433.

16. Triplett, Glover, B., Jr., and Milo B. Tesar. 1960. Effect of compaction, depth of planting, and soil moisture tension on seedling emergence of alfalfa. Agron. J. 52:681-684.